DEVELOPMENT OF A TWO-LINK FLEXIBLE MANIPULATOR

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Specially dedicated to
My beloved mother and father

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ABSTRACT

Flexible manipulator systems exhibit many advantages than the rigid robot systems. Flexible manipulator systems offered less overall costs, less material, small actuators, light in weight and consume less power than the traditional robot (rigid-arm). With the Two-Link Flexible Manipulator (TLFM) systems, various tasks can be done compare to one-link systems. However, this TLFM is rarely used in industry because of the difficulty in controlling the systems. Therefore, this thesis is to develop the mechanical structures of the TLFM and to design the real-time controller for this system so that it can operate smoothly and accurate. The mechanical structures of this two-link flexible manipulator consist of two DC motors, two flexible links, base and couplings. The hardware is interfaced with the computer through the data acquisition card and several analog to digital converter (ADC) and digital to analog converter (DAC). The Real-Time Window Target (RTWT) Toolbox in MATLAB/SIMULINK software is used for controlling the system. The feedback signal from encoder is used for real-time controller development. This flexible manipulator only considered in horizontal plane only.

ABSTRAK

Sistem manipulasi mudah lentur mempunyai banyak kelebihan berbanding sistem robot tegar**.** Antara kelebihannya ialah ia memerlukan kos keseluruhan yang rendah, kurangnya penggunaan material, penggerak yang kecil, bersaiz kecil dan penggunaan kuasa yang minima berbanding sistem tegar. Dengan sistem manipulasi mudah lentur dua lengan, pelbagai tugas boleh dilakukan berbanding sistem manipulasi satu lengan. Walaubagaimanapun, sistem dua lengan ini amat jarang digunakan di industri kerana kesukaran untuk mengawalnya. Maka, tesis ini adalah untuk menghasilkan struktur mekanikal sistem manipulasi mudah lentur dua lengan dan mereka sistem kawalan masa-benar supaya sistem ini dapat beroperasi dengan lancar dan tepat. Struktur mekanikal untuk sistem ini terdiri daripada dua DC motor, dua lengan mudah lentur, tapak dan pengikat. Perkakasan dihubungkan dengan komputer melalui kad capaian data dan beberapa penukar analog ke digital dan digital ke analog. Real-Time Window Target (RTWT) Toolbox di dalam perisian MATLAB/SIMULINK digunakan untuk mengawal sistem ini. Isyarat daripada pengesan kedudukan motor pula digunakan untuk membangunkan kawalan masa-benar. Sistem manipulasi mudah-lentur ini hanya beroperasi pada paksi mendatar sahaja.

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LIST OF ABBREVIATIONS

RLM	-	rigid link manipulators
TLFM	-	two-link flexible manipulator
ADC	-	analog to digital converter
DAC	-	digital to analog converter
RTWT	-	Real-time window target
PID	-	proportional integral differential
PD	-	proportional derivative
LQG	-	linear quadratic Gaussian
LQR	-	linear quadratic regulator
MRLC	-	multirate repetitive learning control
MIMO	-	multi input multi output
PSD	-	position sensitive detector
DOF	-	degree of freedom
DAQ	-	data acquisition
DAS	-	data acquisition system
PC	-	personal computer
PCI	-	peripheral component interconnect
TTL	-	transistor-transistor logic
RAM	-	random access memory
RTC	-	real-time computing
I/O	-	input output
SSE	-	steady state error
DC	-	direct current

LIST OF SYMBOLS

e	-	tracking error
r	-	desired output
u	-	input
y	-	measured output
Kp	-	proportional gain
Ki	-	integral gain
Kd	-	differential gain
Ts	-	time settling
Td	-	time delay
Tc	-	time constant
l	-	length
τ	-	torque
E	-	modulus young
I	-	moment of inertia
	-	mass density per unit volume
A	-	cross section
□	-	angle 1
	-	angle 2
XY	-	stationary axis
X_1Y_1	-	moving coordinates 1
X_2Y_2	-	moving coordinates 2

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CHAPTER 1

INTRODUCTION

1.1 Background of Project

Most of industrial sector use a robot applications as a tool to help them in production. The robot applications, known as an industrial robot, are helpful in doing various tasks such as displace the product, assembled parts, soldering and spray painting. Accurate operation, smooth movement and without vibration are the behaviors that demand in robot applications. The accurate positioning of the end-effectors is important to perform the certain tasks and to avoid a failure in the operation.

Traditionally, rigid link manipulators (RLM) are designed and built in a manner that maximizes stiffness to minimize vibration and allow for good positional accuracy with relatively simple controllers. High stiffness is achieved by using heavy material that limits the rapid motion of the manipulators, increase the sizes of actuators and boost energy consumption. Therefore, much cost is required to perform the traditional robot in industry. RLM are heavy and massive, and their load-carrying capacity is limited to avoid the vibration of the links. Because of that, the rigid robot is inefficient and slow when dealing in industry manufacture.

The Two-Link Flexible Manipulator (TLFM) system is introduced to overcome the problem of the RLM. This flexible manipulator made from the lightweight material and not rigid. Therefore, in general, the flexible manipulator exhibits more advantages than the rigid robots; required less material, lighter in

weight, consumes less power, required small actuators, more transportable, less overall cost and higher payloads to robot weight ratio. It also safer to operate because of reduced inertia. Figure 1.1 shows the example of the TLFM.

Figure 1.1: The two-link flexible manipulator (TLFM)

Over the past two decades the need for high speed manipulation and high payload to weight ratio in robot manipulators has triggered a significant growth in the research and development of the flexible manipulators. Flexible manipulators are a suitable choice to realize such needs since they are light in weight require small sized actuators and low energy consumption. However, the use of these flexible manipulators at a high speed poses challenging problems in designing their control system. The control system must be designed not only for precise tip positioning but also for suppressing the vibrations arising due to the flexible nature of the manipulator.

1.2 Problem Statement

Flexible manipulators are less expensive to manufacture and safer to operate because of reduced inertia. It also can operate in high speed movement with the same or even better precision compared to RLM. However, the manipulators have a vibration problem, become more flexible and more difficult to control accurately due to light in weight and low stiffness. The control difficulty is caused by fact that since the manipulators are distributed, a large number of flexible modes are required to accurately model its behaviors. Further complications arise because of the highly nonlinear nature of the system. Therefore, flexible manipulators have not been favored in industries, as the manipulator is required to have reasonable end-point accuracy in response to input commands. In this respect, accurate models and efficient controllers have to be developed.

1.3 Objectives of the Project

The objectives of this project are:

i. To develop a prototype of a two-link flexible manipulator.
ii. To implement encoder as a feedback signal for controlling the system.
iii. To design and implement a real-time controller for two- link flexible manipulator.

1.4 Scope of the Project

This project is focuses on the design of the mechanical structure of a TLFM and design of real-time controller of the system. The controller is design based on MATLAB/SIMULINK software. Therefore, the interface between hardware and software also required to operate the system. The hardware is interfaced with the computer through the data acquisition card and several analog to digital converter (ADC) and digital to analog converter (DAC). The MATLAB/SIMULINK software is

used to simulate the system where the Real Time Window Target (RTWT) as a main toolbox to implement the system. PID controller has been used as a controller and the Ziegler-Nichols method is used for tuning. The scope of the project also includes the research on encoder as a feedback signal for design of controller. The two degrees of freedom flexible manipulator only operates in horizontal plane only.